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A Socio-Technical Metaverse Development Framework in Higher Education

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Abstract

The concept of the metaverse has recently generated a great deal of attention in academia and industry, with an increasing number of educational institutions expressing interest in its implementation. However, existing studies on metaverse development in higher education are still in their early stages, leaving institutions with little guidance on how to develop and implement a metaverse. Employing socio-technical theory, we propose a comprehensive nine-stage metaverse development framework (MDF) that incorporates both social and technical aspects of a metaverse initiative, thus providing a holistic approach to metaverse development. Leveraging case studies of three large universities and blending them with MDF, our study provides evidence of the applicability of our MDF and offers a better contextual understanding of metaverse development in educational settings. This paper is useful for educational institutions that are developing or considering metaverse initiatives. It contributes to the emerging literature on metaverse development in higher education.

Keywords: Metaverse, development framework, higher education, case study

Introduction

The metaverse is a hypothetical version of the internet that involves various technologies and initiatives aimed at developing a highly immersive, 3D-based internet (Web3) that uses extended reality (XR) technologies, including virtual reality, mixed reality, and augmented reality (Dincelli & Yayla, 2022). Neal Stephenson first introduced the term 'metaverse' in his science fiction novel titled *Snow Crash* (Stephenson, 2003). The metaverse concept gained widespread attention after Mark Zuckerberg renamed his company from Facebook to Meta and announced that the company would focus on metaverse development (Newton, 2021). Since then, an increasing number of practitioners and academics in various domains, including in the educational sector (Dahan et al, 2022; Wang et al, 2022; Zhang et al, 2022), have invested themselves in exploring this new internet form.

Recently, educational institutions have shown an increasing interest in the development of the metaverse for various purposes. Notably, the Hong Kong University of Science and Technology (HKUST), Wuhan University and Tsinghua University have initiated metaverse projects and developed several metaverse applications for smart campuses (HKUST, 2022; Tsinghua University, 2023; Wuhan University, 2022). In addition, the Chinese University of Hong Kong developed a blockchain-based metaverse prototype of its Shenzhen campus to provide students with an interactive experience between the physical and virtual spaces (Duan et al, 2021). The use of the metaverse in the educational sector offers various benefits to educational institutions and associated stakeholders, as outlined below:

- Enhanced learning experience: The use of metaverse technology provides students with a more immersive and engaging learning experience, allowing them to explore and interact with the subject matter in a more interactive and dynamic way (Zhang et al, 2022).
- Enhanced collaboration: Metaverse offers a collaborative platform for educators and students to work together in real time, irrespective of their geographical location, leading to improved peer-to-peer learning, knowledge sharing, and teamwork, particularly in cross-campus settings (Duan et al, 2021).
- Cost-effectiveness: Metaverse technology potentially reduces the costs associated with traditional classroom-based learning, such as travel expenses, physical classroom costs, and material expenses (HKUST, 2022; Wuhan University, 2022).
- Accessibility: Metaverse offers a more accessible learning environment for students who have physical disabilities or who are geographically isolated, allowing them to participate in the learning experience on an equal basis (HKUST, 2022; Tsinghua University, 2023; Wuhan University, 2022).
- Innovative learning: Metaverse technology enables educators to create new and innovative learning experiences that are not possible in a traditional classroom setting, such as virtual simulations and scenarios that provide hands-on experience (Dahan et al, 2022).
- Personalized learning: Metaverse technology provides personalized learning experiences based on individual student needs, interests, and learning styles (Wang et al, 2022).
- Safe learning environment: Metaverse offers a safe and secure learning environment, where students and educators can interact without the risk of physical harm, harassment, or bullying.

By adopting metaverse technology, universities can create smart campuses that align with Industry 4.0 requirements and cater to the needs of hybrid campus models that emerged in response to the COVID-19 pandemic. However, metaverse development is still in its infancy. Although several studies have examined metaverse development frameworks (MDF) in education, they have mainly focused on the technical aspects of the metaverse (Dahan et al, 2022; Wang et al, 2022; Zhang et al, 2022). These frameworks were either derived from literature reviews (Wang et al, 2022; Zhang et al, 2022), or from a single case study (Dahan et al, 2022), and none of them conducted comparative case studies to provide insights into metaverse implementation in higher education. These previous studies overlooked the social aspect of the metaverse and failed to offer a comprehensive socio-technical perspective on metaverse development. Further, none of the studies validated the effectiveness of their proposed frameworks through comparative case studies (Pan et al, 2012; Sarker et al, 2021). To address this gap in understanding, we employ socio-technical theory and propose a nine-stage MDF to guide metaverse development in educational settings. Utilizing the proposed MDF, we examine how large universities develop and implement the metaverse initiative.

The comparative analysis between the specialized Metaverse Development Framework (MDF) and traditional Information Systems Development (ISD) frameworks reveals significant disparities in scope, purpose, and functionalities. While traditional ISD frameworks are tailored for conventional software applications, MDF is uniquely equipped to tackle the intricate challenges of metaverse development (Barry & Lang, 2003; Vassilakopoulou & Hustad, 2023; Zhang et al, 2022). MDF's focus on immersive experiences, real-time interactions, spatial design, collaborative dynamics, and user engagement sets it apart from ISD frameworks, which often overlook the complexities of virtual environments. MDF accommodates the demands of data management, scalability, real-time communication, spatial modelling, and evolving technology landscapes that characterize metaverse projects. This comparison underscores MDF's relevance in bridging the gap between traditional development methodologies and the dynamic metaverse ecosystem, enhancing its importance for current and future IS leaders seeking to venture into the world of virtual environments.

Furthermore, traditional ISD frameworks often fail to effectively address the intricate challenges posed by metaverse development, resulting in enduring disputes. These include the struggle to ensure seamless real-time interactions, accurately model complex spatial dynamics, implement robust data privacy and security measures, integrate experiences across diverse platforms, accommodate dynamic scalability demands, and manage intricate virtual economies (Barry & Lang, 2003; Vassilakopoulou & Hustad, 2023; Zhang et al, 2022). Such disputes arise due to the unique nature of metaverse environments, revealing the limitations of conventional frameworks designed for traditional platforms. To overcome these challenges, the proposed MDF offers a tailored approach, aligning its principles with the specific demands of the metaverse, thereby aiming to resolve these long-standing disputes and elevate the efficacy of metaverse development.

The remainder of this work is organized as follows. Section 2 provides a literature review. Section 3 presents the theoretical foundation of our study and the proposed MDF, followed by a description of the case study methodology applied in this study. Referring to the proposed MDF, section 4 presents the cross-case analysis. Section 5 discusses the implications for practice and contributions to research. Finally, Section 6 concludes the paper.

Literature Review

The concept of the metaverse has attracted significant research attention recently, with several studies making contributions to this emerging field. Table 1 provides an overview of the state-of-the-art research in relation to contribution, methodology, and limitation.

Author	Scope	Contribution	Method	Limitation
Dahan et al, 2022	Metaverse for e-learning environment	Proposes a metaverse framework for e-learning environment	Single case study	Lack of implementation of the proposed framework to prove its effectiveness by integrating real-world cases; overlooks the social aspect
Wang et al, 2022	Metaverse for educational ecosystem	Proposes a framework for metaverse learning environments	Literature review	Lack of testing and fine tuning to align with practices in the real world
Zhang et al, 2022	Metaverse in education	Proposes a framework of the metaverse in education	Literature review	Proposed framework focuses only on the technical aspect of metaverse development, neglecting the social aspect of the metaverse

Nguyen et al, 2022	Blockchain-based metaverse applications	Proposes a blockchain-based framework for metaverse applications called 'MetaChain'	System design; experiment	Interactions among multiple metaverse service providers and metaverse users are not supported by the system
Duan et al, 2021	Metaverse applications for social good	Proposes a three-layer architecture of a metaverse for social good	Prototype development	Lack of comparative real-world case studies to explore the metaverse development
This paper	Metaverse for higher education	Builds a comprehensive socio-technical framework to guide metaverse development	Comparative case study	Only three case studies in educational institutions

Table 1. Summary of previous studies

Dahan et al. (2022) proposed a framework of a metaverse for an e-learning environment (known as 'ELEM'). The primary goal of the ELEM is to ensure optimal performance of the e-learning environment in the metaverse by utilizing various specialized techniques available in the platform and to make the learning environment more interactive and intelligent. Within the framework, an avatar can enable the interaction functions with the integration of metaverse special technologies, which include a digital twin learning environment, virtual learning world, and blockchain. Wang et al. (2022) proposed a framework to construct a metaverse learning ecosystem that encompasses four hubs: the instructional design and performance technology hub, the knowledge hub, the research and technology hub and the talent and training hub. This framework provides a useful guide for developers exploring the potential educational applications of metaverse technology. Zhang et al. (2022) developed a framework of the metaverse in education, in which the learner uses wearable devices to enter the metaverse. The metaverse framework enables intelligent non-player characters, learning analysis, and learning authentication, which are supported by several types of technological infrastructure, including communication and networks, computing technologies, and interaction technologies. Nguyen et al. (2022) proposed a blockchain-based framework, called 'MetaChain'. This framework contains the interaction layer, blockchain layer, and application layer to automate and manage interactions among the metaverse service provider and the metaverse users. Duan et al. (2021) proposed a three-layer metaverse architecture that includes the infrastructure layer in the physical world and the interaction layer and ecosystem layer in the virtual world. The architecture involves relevant supported technologies, such as blockchain, digital twins and artificial intelligence. These researchers also developed a blockchain-based campus metaverse prototype at the Chinese University of Hong Kong's Shenzhen campus to provide their students with an interactive experience between the physical and virtual spaces.

As stated, previous studies have mainly focused on the technical aspects of the MDF, without considering the social aspect of the metaverse. Thus, prior studies have failed to consider the interdependence of the social and technical aspects in the development of metaverse technological systems. Therefore, there is a need for a comprehensive framework that considers the social and technical aspects to guide the entire metaverse development process for educational institutions (Mumford, 2006; Sony & Naik, 2020). Moreover, previous literature highlights the significance of a guidance framework to ensure successful implementation, and the importance of evaluating such a framework through empirical case studies in real-world settings (Pan et al, 2012; Sarker et al, 2021). Thus, our research addresses the gaps in understanding by introducing a comprehensive MDF and conducting multiple case studies of metaverse development in higher education.

Theoretical Foundation and Methodology

This study employed a comparative case study approach to investigate metaverse development in higher education institutions by analyzing three selected cases. The cases were chosen using the principle of theoretical replication based on the degree of stakeholders' attention on the metaverse (Myers & Newman, 2007; Yin, 2009). The three universities selected for this study were HKUST, Wuhan University, and Tsinghua University. This study obtained permission to access the universities and then conducted interviews with relevant stakeholders to collect data. Each case focused on different aspects of metaverse applications using advanced technologies and methods to achieve expected outcomes. The purpose of this study is to construct a development framework to generalize theories concerning various stages of metaverse development and to analyze and present the metaverse development of each case using the framework.

Theoretical foundation and MDF

The theoretical foundation of this paper is socio-technical theory, which emphasizes the interdependence of social and technical elements in the design, implementation, and use of technological systems (Mumford, 2006). This theory suggests that the effectiveness of a technological system is dependent not only on its technical features, but also on its social and organizational context, including the values and practices of its users and the broader social and cultural context in which it is situated (Mumford, 2006). Since socio-technical theory was founded by the London Tavistock Institute, researchers and practitioners have aimed to achieve the joint optimization of social and technical systems, recognizing the importance of addressing human needs when introducing technical systems (Mumford, 2006).

Following socio-technical theory, we argue that metaverse development involves technical and social aspects that are interdependent and mutually influential, and that both these aspects must be considered when developing metaverse systems. Socio-technical theory emphasizes the importance of involving users and stakeholders in the development process of a system, and recognizes that the social, economic, and organizational context of the system can significantly affect its effectiveness and success.

The versatility of the MDF lies in its capacity to accommodate the diverse purposes of different metaverse platforms. Metaverse environments span a wide spectrum, ranging from gaming and entertainment to education, business, and social interaction. Traditional ISD frameworks often struggle to cater to this broad spectrum due to their generalizability. In contrast, MDF's modular and adaptable structure allows it to be tailored to the unique goals and requirements of various metaverse platforms. For instance, consider a metaverse platform designed primarily for educational purposes. The MDF can be customized to prioritize features like seamless integration with educational content, secure access controls for students and teachers, interactive virtual classrooms, and tools for collaborative learning (Vassilakopoulou & Hustad, 2023; Zhang et al, 2022).

Furthermore, the socio-technical aspects of MDF can be tailored to the specific user communities of different metaverse platforms. A social metaverse might emphasize user interaction and community-building features, while a business-oriented metaverse could prioritize networking, collaboration, and resource sharing. MDF's ability to encompass diverse purposes is rooted in its holistic approach that seamlessly integrates both technological and social considerations. By recognizing the unique needs of each metaverse platform, MDF ensures that the resulting virtual environments are not only functional but also align with their intended goals, fostering meaningful user experiences and achieving the varied purposes of different metaverse platforms.

Drawing on socio-technical theory and previous literature (Dahan et al, 2022; Nguyen et al, 2022; Wang et al, 2022; Zhang et al, 2022), this paper proposes a theoretical MDF that incorporates both technical and social aspects. The proposed socio-technical framework for metaverse development consists of nine major stages, each of which plays a crucial role in the development and implementation of the metaverse systems. The framework begins with the design and development of the metaverse infrastructure and architecture, followed by the creation of a metaverse platform and visualization tools that allow users to interact with the virtual environment. The framework also includes metaverse data and identity management to ensure privacy and security, as well as user experience design to create an immersive and engaging environment. Testing and evaluation procedures are also crucial to ensure that the metaverse systems are functioning as intended. The framework prioritizes social interaction and communication, economics and governance, and the collection of feedback from users for continuous improvement. In addition, each stage of the MDF can be flexibly applied across these platforms. In the conceptualization phase, different platforms might focus on distinct user needs and experiences. The design and development of the virtual environment, avatars, communication tools, and interaction mechanics would vary accordingly. During the data management and privacy stage, educational platforms might prioritize stringent data protection for student information, while entertainment-focused platforms might concentrate on user engagement analytics. By following this socio-technical framework, developers can create a metaverse system that is scalable, reliable, and user-friendly, with an effective governance model. Figure 1 depicts the proposed MDF, which encompasses the following nine stages:

- Stage 1—Metaverse Infrastructure and Architecture: The infrastructure and architecture of the MDF involve the design and development of servers, networks, and computing resources that support the virtual environment. The metaverse requires a scalable and reliable infrastructure to handle large amounts of data and provide low-latency communication between users.
- Stage 2—Metaverse Platform and Visualization Tools: The MDF requires a platform and tools to create, manage, and interact with the virtual environment. The platform should be accessible and user-friendly, allowing users to easily create and customize their avatars, virtual objects, and virtual environments. The tools should include content creation tools, programming languages, and software development kits that allow developers to create custom applications and games.
- Stage 3—Metaverse Data and Identity Management: This stage of the MDF involves the collection, storage, and management of large amounts of user data, including personal information, preferences, and behavior. It ensures the privacy and security of user data while also providing users with control over their personal information. Identity management is also crucial in this stage because users must be able to identify themselves and authenticate their identities to access specific features and content.
- Stage 4—User Experience Design: The MDF should prioritize user experience design to ensure that the metaverse systems are immersive, engaging, and user-friendly. User experience design should consider user needs and preferences, as well as provide intuitive navigation and interaction options.
- Stage 5—Testing and Evaluation: The MDF should include testing and evaluation procedures to ensure that the metaverse systems are functioning as intended. This includes testing for performance, scalability, and security, as well as user testing to evaluate the user experience.
- Stage 6—Social Interaction and Communication: The metaverse is a social environment that allows users to interact and communicate with each other. The MDF must provide various communication channels, such as voice and text chat, and support real-time interactions between users. It should also allow users to form groups, communities, and social networks based on shared interests and preferences.
- Stage 7—Economics and Governance: The MDF involves the creation and exchange of virtual goods and services, which require an economics framework and governance model. The metaverse should have a stable and transparent economy that allows users to exchange virtual currencies, assets, and services. The governance model should ensure that the metaverse operates fairly and efficiently, with clear rules and regulations that govern user behavior and content creation.
- Stage 8—Feedback from Users: This stage highlights the importance of collection of user feedback and users' perspective of the metaverse systems that can help improve and iterate the metaverse systems.
- Stage 9—Continuous Improvement: The final stage of MDF highlights continuous improvement to ensure that the metaverse systems evolve with user needs and expectations. This includes monitoring emerging technologies and trends, as well as implementing updates and improvements to the platform and tools.

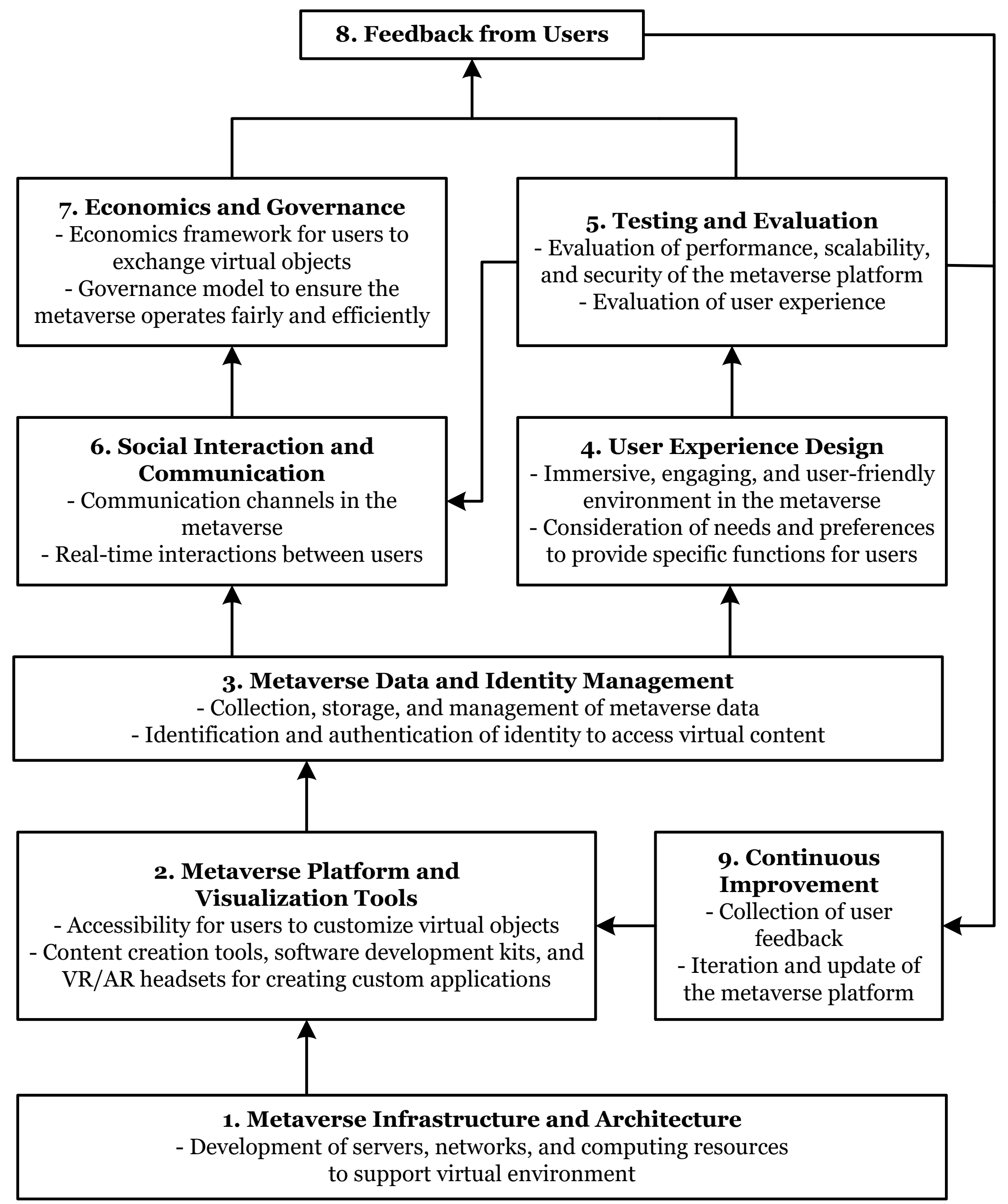

Figure 1. Metaverse development framework

Data collection

Utilizing the MDF, we examined metaverse development in three large universities. For all three cases discussed in this paper, we collected primary data collection. The method for gathering data from the MetaHKUST project involved conducting fieldwork and holding face-to-face interviews with key members of the project in mid-September 2022. The Wuhan University field research was conducted at the end of the same month by interviewing members of the research team responsible for building the metaverse of the entire campus of Wuhan University, as well as their professor. In October 2022, interviews were conducted with the key members of the Tsinghua University team who developed the university's metaverse platform. These researchers also participated in publishing the world's first research report on metaverse development. Thus, we also gathered secondary data in this case study, that is, we examined the Tsinghua Metaverse Development Research Report 3.0.

The field research took approximately two days and each interview lasted approximately one hour, with questions centering on the anticipated project outcomes, the current stage of development, information about the development team and environment, including specific questions about software, hardware, the platform, and visualization tools. Additionally, the questions aim to elicit the benefits and challenges of using a metaverse based on blockchain and digital twin technology in smart campuses, and the methods of collecting, storing, and managing data as well as authenticating identity in the virtual world. Other interview questions also related to our proposed framework, including questions about the ways to ensure an immersive, engaging, and user-friendly metaverse system; the process of testing and evaluation; the functions of social interaction and communication; and plans for building economic frameworks and governance models. Finally, feedbacks from users or other stakeholders are obtained to continuously improve the metaverse applications. Recordings were made of all the interviews, and these were then transcribed.

Data analysis

During the data analysis phase of this research, an iterative process was employed that involved analyzing the empirical data alongside relevant metaverse literature. This process was continued until the findings of the case studies had been explored comprehensively, and there were no further data to collect and analyze (Darke et al, 1998).

We analyzed the findings by reviewing recordings taken during fieldwork and reading transcripts to extract relevant and important information that could be used in the study. Based on the primary data that were collected, we employed the MDF to analyze and discuss the nine stages of metaverse development for the three cases, as detailed in the subsequent section.

Cross-case analysis

This paper implements MDF as a use case in educational settings. The metaverse holds substantial promise for education through immersive learning experiences using virtual reality (VR) and augmented reality (AR), virtual classrooms fostering global interactions, collaborative environments enhancing teamwork and critical thinking, simulations for safe practical training in fields like medicine and engineering, adaptive learning for diverse needs, global learning communities promoting cultural awareness, lifelike simulations for historical and scientific understanding, and personalized learning paths driven by advanced analytics and AI. Explicitly highlighting these metaverse applications and benefits in education elucidates its potential to transform teaching and learning approaches, fostering engagement, inclusivity, and preparation for a dynamic future.

This research employs a multiple case study approach to investigate how educational institutions develop a metaverse. As shown in Table 2, the three case studies reveal three aspects of metaverse development in the educational setting. The three metaverse projects utilize different technologies and achieve different functions of metaverse applications in both theoretical and practical research context.

	HKUST	Wuhan University	Tsinghua University
Focus Area	Digital twin campuses in the metaverse	Metaverse campus using remote sensing mapping and photogrammetry technologies	Industrialization of the metaverse and cultural attributes of metaverse
Expected Outcomes	Establishing the metaverse of the two campuses to achieve educational functions using digital twin and blockchain	Establishing a metaverse campus and interactive applications for various campus scenarios in the metaverse	Establishing industrialization of the metaverse and producing their Metaverse Development Research Report 3.0

Current State	At the initial stage, virtual classrooms were built as pilots so far.	The initial version of the metaverse application is nearly completed.	The metaverse platforms is at the pilot stage and the Metaverse Development Research Report 3.0 was published.
Stage 1: Metaverse Infrastructure and Architecture	• XR classrooms with sensors • 3D camera • crowdsourced scanning	• UAV oblique mapping • nap-of-the-object photogrammetry technologies • lidar scanning equipment • automatic modeling software	• Artificial intelligence humanoid robot for metaverse applications in various industrial scenarios
Stage 2: Metaverse Platform and Visualization Tools	• Unity 3D • Web3D • Unreal Engine • HoloLens 2	• ContextCapture • 3D Max • Unity 3D • mobile application	• AR smartglass • NFT trading service platform • metaverse display and operation platform
Stage 3: Metaverse Data and Identity Management	• Data collected from sensors, APIs, web crawlers, or user inputs • cloud storage services and distributed databases • username and password authentication • two-factor authentication • biometric recognition	• Collect data using satellites, drones and lidar • process data to form a real-scene digital foundation • select useful data uploaded by users • store data on a cloud server • username and password authentication	• Data stored into the blockchain network • obtain lifelong ownership of the NFT domains when creating NFT accounts • indivisible NFTs are used for identity verification
Stage 4: User Experience Design	• Development of natural interactions • navigation functions	• real-world 3D technology to build digital foundation • real geographic coordinates and positioning function • enabling campus parkour, digital human interaction, and virtual classrooms functions	• Use of AR glasses to connect reality and the virtual world • virtual companions
Stage 5: Testing and Evaluation	• Functionality testing • network testing • user experience testing	• Carrying capacity testing • network and hardware conditions testing	• Network testing • user experience testing
Stage 6: Social Interaction and Communication	• Voice and text chat channels • real-time interactions between users	• Alibaba Cloud servers to enable text-based interaction among users	• Create own virtual image and interact with others • establish social connections and manage social assets in the metaverse

Stage 7: Economics and Governance	• Metaverse Governance Committee • governance framework and rules • user identity and data management • security and risk management • community participation and feedback mechanism	• Prototype of a trading platform based on a campus real-life metaverse • use blockchain and virtual currency for transactions	• Basic operating rules • management rules • governance rules
Stage 8: Feedback from Users	• Highlight the important role of digital twin in the metaverse • suggest the use of metaverse to enhance campus security	• Indicate it is necessary to integrate digital twin and blockchain technology (e.g., NFTs) into the metaverse	• Suggest five development modules of the metaverse industrialization
Stage 9: Continuous Improvement	• Add more social functions • improve the governance models • establish a metaverse of the entire campuses	• Develop a unified database platform for data management • conduct performance, scalability, and security testing • open up more practical application functions	• Facilitate the industrialization of the metaverse • continuous update of the metaverse development report

Table 2. A comparison of the three cases

When comparing the three cases, it becomes clear that they differ in relation to their focus areas, expected outcomes, current stage, and relevance to the MDF, as shown in Table 2. For example, HKUST aims to enhance campus security and establish metaverse classrooms within their campuses by utilizing digital twin technology. This technology allows for the creation of a virtual replica of the physical campuses in Hong Kong and Guangzhou (China), which can be used to improve campus management and student learning experiences. Wuhan University focuses on using remote sensing mapping and photogrammetry technologies to establish a virtual campus with various functions, such as multiplayer interaction and virtual campus tours. This virtual campus can be used to simulate real-world scenarios and provide students with a more immersive and interactive experience on a virtual campus. Tsinghua University aims to facilitate the industrialization of the metaverse and conduct research into the cultural attributes of the metaverse.

Despite these differences, the three universities share some similarities in their approach to metaverse implementation. All three projects are in the initial stages of development, with a focus on building prototypes and pilot testing. Additionally, all three universities aim to enhance the educational experience through the use of metaverse, whether that is through improving campus security, creating a more immersive learning environment, or facilitating the industrialization of the metaverse. However, they all face challenges in the implementation process, such as the high demand for network servers and the high cost of developing metaverse platforms. These similarities and differences highlight the need for a comprehensive and contextualized MDF that considers the socio-technical nature of the metaverse to ensure successful implementation of metaverses in higher education.

Notably, the evidence from the case studies confirms the applicability of our proposed MDF because all nine stages of the framework were utilized by the three cases, considering both technical and social aspects. Hence, the proposed nine-stage MDF in Figure 1 can serve as a guide for educational institutions to plan and execute metaverse projects effectively and efficiently. This framework emphasizes the importance of adopting a socio-technical approach within the development process, whereby critical components such as infrastructure, user experience design, and social interaction are considered. By following the MDF, educational institutions can ensure that their metaverse projects align with their goals and expectations, and that the development process considers all critical aspects.

Discussion

This study has several implications for practice. First, our paper shows that a comprehensive social-technical MDF offers educational institutions and metaverse stakeholders a systematic and structured approach to future metaverse development. By adopting this framework, educational institutions can ensure that the metaverse platform they create is not only technically feasible, but also socially and culturally appropriate. This can lead to a higher degree of adoption and utilization of the metaverse platform, ultimately enhancing educational stakeholders' experience in the metaverse.

Second, this study also demonstrates the importance of prioritizing user experience design and social interaction and communication in metaverse development. Practitioners should aim to create a user-centered design that focuses on the needs of users, incorporating feedback from users and other stakeholders (e.g., developers and managers) throughout the development process. This feedback can help to ensure that the metaverse platform provides a positive user experience. Additionally, metaverse stakeholders should pay attention to the importance of continuous feedback loops between users and developers, enabling ongoing improvements to the platform based on user needs. By prioritizing user experience design; social interaction and communication; and feedback from users and stakeholders, practitioners can create a metaverse platform that is both technically and socially appropriate, enhancing the overall experience for all involved.

Third, to ensure that their metaverse platforms remain effective, metaverse stakeholders should continually monitor and assess the platform’s performance and user feedback. This can involve conducting surveys, focus groups, and usability testing to gather information from users and stakeholders. Practitioners can employ our MDF as a guide for metaverse development, following the nine stages to ensure a systematic and rigorous approach. By adopting this MDF, institutions can potentially avoid common pitfalls and ensure that their metaverse initiatives are successful in achieving their intended goals.

This paper makes several contributions to the research on metaverse development. First, this study identifies the need for a comprehensive socio-technical framework to guide the entire process of metaverse development. It discusses the limited research that currently exists and fills the gap in knowledge by offering a focused and in-depth study of the current state of metaverse development in higher education, highlighting the importance of considering both the social and technical aspects of metaverse development.

Second, this study proposes a socio-technical MDF that identifies nine key stages of the metaverse development process. Unlike prior studies that mainly focused on technical aspects (Dahan et al, 2022; Wang et al, 2022; Zhang et al, 2022), this framework incorporates both social and technical considerations, providing a comprehensive guide for researchers and practitioners. The MDF comprises nine key stages spanning the social and technical aspects of the metaverse to offer a more holistic approach to metaverse development in educational settings.

Third, this study conducts multiple case studies to understand metaverse development in different university settings. By analyzing the cases of HKUST, Wuhan University, and Tsinghua University and blending them with our MDF, this study confirms the utilities of the MDF and provides a contextual understanding of each of the nine stages of metaverse development in higher education settings, which can help inform future metaverse research and practice. These case studies provide valuable insights into the socio-technical aspects that influence the development of a metaverse in educational settings.

While the Metaverse Development Framework (MDF) offers a comprehensive approach to metaverse development, there are potential challenges and limitations that need to be considered. One challenge is the dynamic and rapidly evolving nature of technology. As technologies change, the MDF may need to be updated to stay relevant. To address this, a strategy would be to incorporate a regular review process that ensures the framework aligns with emerging trends. Furthermore, collaboration and stakeholder engagement can be challenging due to differing perspectives and interests. To address this, the MDF could emphasize the importance of communication and collaboration throughout the development process, providing guidelines for effective stakeholder engagement.

Furthermore, the scalability of the MDF could also pose challenges, particularly as metaverse projects vary in size and scope. To tackle this, the framework could offer guidelines for scaling up or down based on project requirements, thereby catering to projects of different scales. In addition, resource constraints might limit the implementation of the MDF. Addressing this challenge involves advocating for its value through case studies and empirical evidence, demonstrating the positive impact of following the framework.

Conclusion

Employing socio-technical theory, this paper proposed a comprehensive nine-stage MDF that incorporates both social and technical aspects of the metaverse initiative, thereby offering a systematic and rigorous approach to metaverse development. Leveraging case studies of three major universities in China and blending them with our MDF, this research confirmed the applicability and utilities of the proposed MDF and revealed insights into contextual metaverse development in educational settings. The contributions of this paper can help advance knowledge and understanding of metaverse development in higher education and provide valuable guidance for future research and practice in this area.

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References

Barry, C., & Lang, M. (2003). A comparison of ‘traditional’ and multimedia information systems development practices. *Information and Software Technology*, *45*(4), 217-227.

Dahan, N. A., Al-Razgan, M., Al-Laith, A., Alsoufi, M. A., Al-Asaly, M. S., & Alfakih, T. (2022). Metaverse framework: A case study on E-learning environment (ELEM). Electronics, 11(10), 1616.

Dincelli, E., & Yayla, A. (2022). Immersive virtual reality in the age of the Metaverse: A hybrid-narrative review based on the technology affordance perspective. The journal of strategic information systems, 31(2), 101717.

Duan, H., Li, J., Fan, S., Lin, Z., Wu, X., & Cai, W. (2021, October). Metaverse for social good: A university campus prototype. In Proceedings of the 29th ACM international conference on multimedia (pp. 153-161).

Darke, P., Shanks, G., & Broadbent, M. (1998). Successfully completing case study research: combining rigour, relevance and pragmatism. Information systems journal, 8(4), 273-289.

HKUST (2022) HKUST to launch World's first twin campuses in Metaverse, HKUST to Launch World's First Twin Campuses in Metaverse | The Hong Kong University of Science and Technology. Available at: https://hkust.edu.hk/news/research-and-innovation/hkust-launch-worlds-first-twin-campuses-metaverse (Accessed: February 14, 2023).

Mumford, E. (2006). The story of socio-technical design: Reflections on its successes, failures and potential. Information systems journal, 16(4), 317-342.

Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. Information and organization, 17(1), 2-26.

Newton, C. (2021) Mark in the metaverse, The Verge. Available at: https://www.theverge.com/22588022/mark-zuckerberg-facebook-ceo-metaverse-interview (Accessed: January 19, 2023).

Nguyen, C. T., Hoang, D. T., Nguyen, D. N., & Dutkiewicz, E. (2022, June). Metachain: A novel blockchain-based framework for metaverse applications. In 2022 IEEE 95th Vehicular Technology Conference:(VTC2022-Spring) (pp. 1-5). IEEE.

Pan, S. L., Pan, G., & Leidner, D. E. (2012). Crisis response information networks. Journal of Association of Information Systems, 13(1), 31.

Sarker, S., Henningsson, S., Jensen, T., & Hedman, J. (2021). The use of blockchain as a resource for combating corruption in global shipping: an interpretive case study. Journal of Management Information Systems, 38(2), 338-373.

Sony, M., & Naik, S. (2020). Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical model. *Technology in society*, *61*, 101248.

Stephenson, N. (2003). Snow crash: A novel. Spectra.

Tsinghua University (2023) Metaverse Development Research Report, Tsinghua University: Metaverse Development Research Report (version 3.0, 256 pages). Available at: https://inf.news/en/news/8f2980ec20425be24443fe2f38f4b92b.html (Accessed: February 25, 2023).

Vassilakopoulou, P., & Hustad, E. (2023). Bridging digital divides: a literature review and research agenda for information systems research. *Information Systems Frontiers*, *25*(3), 955-969.

Wang, M., Yu, H., Bell, Z., & Chu, X. (2022). Constructing an Edu-metaverse ecosystem: a new and innovative framework. IEEE Transactions on Learning Technologies, 15(6), 685-696.

Wuhan University (2022) The first metaverse virtual campus of Wuhan University built by a research team from WTUSM, The first Wuhan University metaverse virtual campus, built by the Seventh Brigade!. Available at: https://m.thepaper.cn/baijiahao_19768607 (Accessed: February 16, 2023).

Yin, R. K. (2009). Case study research: Design and methods (Vol. 5). sage.

Zhang, X., Chen, Y., Hu, L., & Wang, Y. (2022). The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. Frontiers in Psychology, 13.